Appendix D: EPA's Legal Authority for Proposing Gasoline Sulfur Controls

We are proposing gasoline sulfur controls pursuant to our authority under Section 211(c)(1) of the Clean Air Act. This section gives us the authority to "control or prohibit the manufacture, introduction into commerce, offering for sale, or sale" of any fuel or fuel additive (A) whose emission products, in the judgment of the Administrator, cause or contribute to air pollution "which may be reasonably anticipated to endanger the public health or welfare" or (B) whose emission products "will impair to a significant degree the performance of any emission control device or system which is in general use, or which the Administrator finds has been developed to a point where in a reasonable time it would be in general use" were the fuel control or prohibition adopted. The following sections describe current our regulatory requirements that affect gasoline sulfur content, and explain our bases for proposing to control gasoline sulfur under Section 211(c)(1).

A. EPA's Current Regulatory Requirements for Gasoline

We currently have regulatory requirements for conventional and reformulated gasoline (RFG), adopted under Sections 211(c) and 211(k) of the Act. RFG is required to be sold in certain ozone nonattainment areas. Gasoline sold in the rest of the country is subject to the conventional gasoline requirements. See 40 CFR part 80.

Both the RFG and conventional gasoline (CG) requirements include a NOx performance standard that requires refiners to achieve a certain level of NOx control compared to1990 baseline levels. As a practical matter, compliance with this performance standard results in limiting sulfur levels in RFG. The NOx reductions required by the Phase 2 RFG requirements, effective on January 1, 2000, are expected to result in RFG sulfur levels of about 150 ppm. In addition, EPA's regulations require compliance with the RFG and CG standards (including the NOx performance standard) to be calculated using the Complex Model beginning in 1998. This model contains range limits for RFG for a number of fuel parameters that affect NOx performance, including a range of zero to 500 ppm for sulfur. Therefore, the requirement to use the Complex Model effectively limits sulfur levels in RFG to no more than 500 ppm. The sulfur Complex Model range limit for RFG is the only direct regulation of sulfur content under Section 211(c)(1). However, the NOx performance standards for RFG and CG have an indirect effect on sulfur content.[a]

[a]Because sulfur is directly or indirectly controlled by EPA requirements, and will be controlled directly under today's proposal, states are preempted from initiating sulfur control programs unless they are identical to the federal requirements. See the discussion in Section V.B on this subject.

All gasoline is subject to Section 211(f) of the Act, which prohibits fuel or fuel additive manufactures from introducing into commerce, or increasing the concentration in use of, any fuel or fuel additive for general use in light duty motor vehicles which is not “substantially similar” to the fuel used in the certification of model year 1975 or later vehicles or engines. We have interpreted "substantially similar" for unleaded gasoline to include any gasoline meeting the 1988 ASTM specifications for unleaded gasoline (ASTM D 4814-88[b]), which limits the sulfur content of unleaded gasoline to 0.1 weight percent (1000 ppm) sulfur.

B. How the Proposed Gasoline Sulfur Control Program Meets the CAA Section 211(c) Criteria

Under Section 211(c)(1), EPA may adopt a fuel control if at least one of the following two criteria is met: 1) the emission products of the fuel cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare, or 2) the emission products of the fuel will significantly impair emissions control systems in general use or which would be in general use were the fuel control to be adopted. We are proposing to control sulfur levels in gasoline based on both of these criteria. Under the first criterion, we believe that emissions products of sulfur in gasoline used in Tier 1 and LEV technology vehicles contribute to ozone pollution, air toxics, and PM. Under the second criterion, we believe that gasoline sulfur in fuel that will be used in Tier 2 technology vehicles will significantly impair the emissions control systems expected to be used in such vehicles. The following sections summarize our analysis of each criterion.

1. Health and Welfare Concerns of Air Pollution Caused by Sulfur in Gasoline

We believe that the emission products of gasoline sulfur contribute to air pollution that can reasonably be anticipated to endanger public health and welfare. The combustion products of the sulfur-containing compounds in gasoline (SO_2 and other sulfur oxides) contribute to air pollution that has adverse impacts on public health and welfare. The greatest impact of gasoline sulfur on pollution is the increase in emissions of hydrocarbons (including hazardous air pollutants such as benzene and 1,3-butadiene), NOx, particulate matter, and compounds such as nitrates and sulfates that become particulates in the atmosphere. As explained below and in the RIA, these increased emissions result primarily from the adverse impact of high sulfur levels on the automotive catalysts used in the vehicles which have recently entered the fleet or will be used to comply with the proposed Tier 2 standards. The health and welfare implications of the emissions of these compounds are discussed in greater detail in Section III of the Preamble.

Section 211(c)(2)(A) requires that, prior to adopting a fuel control based on a finding that

[b]Standard Specification for Automotive Spark-Ignition Engine Fuel

the fuel's emission products contribute to air pollution that can reasonably be anticipated to endanger public health or welfare, EPA consider "all relevant medical and scientific evidence available, including consideration of other technologically or economically feasible means of achieving emission standards under [section 202 of the Act]." EPA's analysis of the medical and scientific evidence relating to the emissions impact of sulfur in gasoline is described in more detail in the RIA.

2. Impact of Gasoline Sulfur Emission Products on Emission Control Systems

EPA believes that sulfur in gasoline can significantly impair the emissions control technology of vehicles designed to meet the proposed Tier 2 emissions standards. We know that gasoline sulfur has a negative impact on vehicle emission controls. This is not a new development. Vehicles depend on the catalytic converter to oxidize or reduce emissions of HC, CO, and NOx. Sulfur and sulfur compounds attach or "adsorb" to the precious metals which are required to convert these emissions. Sulfur also blocks sites on the catalyst designed to store oxygen which are necessary to optimize NOx emissions conversions. While the amount of sulfur contamination can vary depending on the metals used in the catalyst and other aspects of the design and operation of the vehicle, some level of sulfur contamination will occur in any catalyst.

For older vehicles designed to meet Tier 0 and Tier 1 emission standards, this sulfur contamination increases emissions of NMHC and NOx by almost 17 percent when one of these vehicles is operated on gasoline containing 330 ppm sulfur (approximately the current national average sulfur level) compared to operation on gasoline with 30 ppm sulfur (which is close to California's current average sulfur level, and is the average sulfur level proposed in this notice). Thus, Tier 0 and Tier 1 vehicles have higher emissions when they are exposed to sulfur levels substantially higher than the proposed sulfur standard. This increase is generally not enough to cause a vehicle to exceed the full useful life emission standards in practice, because car manufacturers design the vehicles with a margin of safety to compensate for deterioration in emissions performance over the life of the vehicle. However, it does lead to greater in-use emissions than achieved with the proposed control on gasoline sulfur content.

The sulfur impact on the catalysts used in later model vehicles is clearly significant. High sulfur levels have been shown to significantly impair the emissions control systems of cleaner, later technology vehicles. The California LEV standards and Federal NLEV standards, as well as California's new LEV-II standards and our proposed Tier 2 standards, require catalysts to be extremely efficient to adequately reduce emissions over the full useful life of the vehicle. Recent test programs conducted by the automotive and oil industries show that LEV and ULEV vehicles can experience, on average, a 40 percent increase in NMHC and 134 percent increase in NOx emissions when operated on 330 ppm sulfur fuel compared to 30 ppm sulfur fuel. This level of emissions increase is significant enough that it would undermine the technical and economic feasibility of the Tier 2 standards proposed today.

This level of impact on emission control system efficiency would mean actual in-use emissions reductions from the proposed tier 2 standards would be undercut to such a degree that the resulting limited in-use emissions reductions would not warrant the expense imposed by the Tier 2 standards, and would not achieve the in-use emissions reductions from these motor vehicles needed to address the air quality problems described elsewhere in this notice. In addition, the concerns about irreversibility of the damage to the catalyst mean it would not be feasible to design an emission control system that would offset this level of impact on the efficiency of the control system in order to comply over the useful life of the vehicles. Average sulfur levels in the U.S. are currently high enough to significantly impair the emissions control systems in new technology vehicles, and to potentially cause these vehicles to fail emission standards required for vehicles up through 100,000 miles (or more) of operation.

Based on this information, we have concluded that the sensitivity of automotive catalysts to sulfur has increased to such a degree in vehicle technology currently available, and expected to be used to meet the proposed Tier 2 standards, that sulfur levels in gasoline must be reduced to enable these catalysts to operate properly. Not only will harmful emissions from vehicles on the road today be reduced through lowering gasoline sulfur levels, but the emissions control systems expected to be used to attain the proposed Tier 2 standards will be significantly impaired if sulfur levels are not substantially reduced from current levels. A lesser reduction in gasoline sulfur levels nationwide would likely require us to reduce the stringency of the proposed Tier 2 standards. The same kind of analysis for Tier 0 and Tier 1 vehicles could arguably support a determination that gasoline sulfur levels significantly impair the emissions control systems of these vehicles. This is because the effect of sulfur in reducing catalyst efficiency and thereby increasing emissions exists for all vehicles at issue here (Tier 0 through tier 2), presenting more a question of difference in degree than in the nature of the effects.

Sulfur in gasoline can also significantly impair the onboard diagnostic (OBD) systems in current and future vehicles. EPA regulations require all vehicles to be equipped with OBD systems that monitor catalyst performance and other emissions-related performance, and warns the vehicle owner if the emissions control system is not functioning properly. In a 1997 staff paper, EPA concluded that sulfur in gasoline can directly impact OBD systems by affecting the OBD system's oxygen sensors.[1] It is possible that high sulfur levels may impair the OBD system in such a way that it does not recognize an improperly functioning catalyst, and fails to warn the owner. In addition, it is not clear that the conditions which may reverse some of sulfur's effect on the catalyst will also reverse this impact on the OBD system's oxygen sensors. The impact of sulfur on OBD systems in cleaner technology vehicles may be even more significant, since the OBD malfunction thresholds are expressed as multiples of the applicable hydrocarbon standard. Therefore, the impact of sulfur on OBD systems in vehicles meeting more stringent hydrocarbon standards would be more significant in relative terms.

3. Sulfur Levels that Tier 2 Vehicles Can Tolerate

We believe that Tier 2 vehicles that operate on gasoline will have to use fuel with sulfur levels no greater than 80 ppm to avoid significant impairment of their emissions control systems. Furthermore, on average, these vehicles will not be able to be exposed to sulfur levels substantially greater than 30 ppm to achieve the desired emission performance and avoid significantly impairing the emissions control system. These conclusions are based on data collected on vehicles currently sold in California or being developed for sale in California and the Northeast (the latter under the NLEV program).

The test data from industry test programs and individual automotive and catalyst manufacturers show that even very low levels of sulfur have some impact on catalyst performance. The data also show that the greatest increase in emissions comes as the sulfur level is increased from the lowest levels. At higher sulfur levels, the catalyst is approaching the point of being saturated with sulfur, and its performance is already impaired, such that an additional increase in sulfur content has a smaller impact on emissions. This trend applies generally for all of the regulated pollutants (NMHC, CO, NOx). However, for most vehicles, the impact is greatest for NOx.

While the overall trends demonstrate that high sulfur levels significantly impair the emissions control system of newer technology vehicles, the data also shows that some vehicles are much less sensitive to sulfur than others. The reasons for these vehicle-to-vehicle variations are not fully understood. We have identified a number of factors involved in the vehicle design and operation which appear to contribute to the variation. To summarize briefly, sulfur sensitivity is impacted not only by the catalyst formulation (the types and amounts of precious metals used in the catalyst) but also by the following factors:

the materials used to provide oxygen storage capacity in the catalyst, as well as the general design of the catalyst,

- the location of the catalyst relative to the engine, which impacts the temperatures inside the catalyst,

the mix of air and fuel entering the engine over the course of operation, which is varied by the engine's computer in response to the driving situation and affects the mix of gases entering the catalyst from the engine, and

the speeds the car is driven at and the load the vehicle is carrying, which also impact the temperatures experienced by the catalyst.

All of these factors contribute not only to the degree to which sulfur will poison a catalyst, but also whether and how easily the sulfur will be removed during a vehicle's normal operation. This cycle of sulfur collection (adsorption) and removal (desorption) in the catalyst is what ultimately affects sulfur's net impact on emissions and the emissions control system, both short and long term. Since these factors vary for every vehicle, the sulfur impact varies for every vehicle to some degree. There is no single factor that guarantees that a vehicle will be very sensitive or very insensitive to sulfur. None of the data that we have reviewed indicates a vehicle design which is completely insensitive to sulfur, or even capable of tolerating average sulfur levels above 30 ppm without a significant impairment of its emissions control system.

Based on the data and information obtained from catalyst manufacturers, we have also concluded that there are no viable emission control alternatives that could achieve the same level of emission standards without reducing commercial gasoline sulfur levels, as explained in the next section.

4. Sulfur Sensitivity of Other Catalysts

Section 211(c)(2)(B) requires that, prior to adopting a fuel control based on a significant impairment to vehicle emissions control systems, EPA consider available scientific and economic data, including a cost benefit analysis comparing emissions control devices or systems which are or will be in general use that require the proposed fuel control with such devices or systems which are or will be in general use that do not require the proposed fuel control. As described below, we conclude that the emissions control systems expected to be used to meet the proposed Tier 2 standards would be significantly impaired by operation on high sulfur gasoline. Our analysis of the available scientific and economic data can be found in the Preamble, including an analysis of the environmental benefits of the proposed control, an analysis of the costs and the technological feasibility of controlling sulfur to the proposed levels, and a cost-benefit analysis of the proposed sulfur control and Tier 2 vehicle emissions standards. Under Section 211(c)(2)(B), EPA is also required to compare the costs and benefits of achieving vehicle emissions standards through emissions control systems that are not sulfur-sensitive, if any such systems are or are will be in general use.

We have determined that there are not (and will not be in the foreseeable future) emission control devices available for gasoline-powered vehicles that can meet the proposed Tier 2 emission standards and would not be significantly impaired by gasoline with high sulfur levels. All catalysts are sensitive to sulfur to some degree. As explained in Section IV.A of the Preamble, we cannot identify one or more factors that definitively determine sulfur sensitivity, because sulfur sensitivity seems to be due to a combination of many factors that vary by vehicle. Hence, it is not possible to identify alternative designs that can tolerate existing (or even intermediate) sulfur levels and that can reasonably be expected to be applied to all cars and light trucks meeting Tier 2 standards.

As described in Section IV.A. of the Preamble, EPA anticipates that all the gasoline vehicle technologies expected to be used to meet the proposed Tier 2 standards will require the use of low sulfur gasoline. If we do not control gasoline sulfur to the proposed levels, we will not be able to set Tier 2 standards as stringent as those we are proposing today. Moreover, vehicles already on the road would continue to emit at higher levels than they would if operated on low sulfur fuel. Consequently, EPA concludes that the benefits that would be achieved through implementation of the proposed vehicle and sulfur control programs cannot be achieved through the use of emission control technology that is not sulfur-sensitive.

This also means that if EPA were to adopt vehicle emissions control standards without controlling gasoline sulfur content, the standards would be significantly less stringent than those proposed today based on what would be technologically feasible with current sulfur levels. The cost of the vehicle emissions control technology would likely be similar to the costs of meeting the proposed Tier 2 standards, because the same technologies would be used. However, the emissions benefits of those technologies would be significantly less than what would be achieved by the program proposed today, because the emissions control technology for gasoline vehicles currently in use, and expected to be used in the future, would be significantly impaired by high sulfur fuel.

5. Effect of Gasoline Sulfur Control on the Use of Other Fuels or Fuel Additives

Section 211(c)(2)(C) requires that, prior to prohibiting a fuel or fuel additive, EPA establish that such prohibition will not cause the use of another fuel or fuel additive "which will produce emissions which endanger the public health or welfare to the same or greater degree" than the prohibited fuel or additive. This finding is required by the Act only prior to prohibiting a fuel or additive, not prior to controlling a fuel or additive. Since EPA is not proposing to prohibit sulfur in gasoline, but rather to control the levels of sulfur in gasoline, this finding is not required prior to regulation. However, EPA does not believe that the proposed sulfur control will result in the use of any other fuel or additive that will produce emissions that will endanger public health or welfare to the same or greater degree as the emissions produced by gasoline with uncontrolled sulfur levels.

We believe that gasoline formulated to meet the proposed low sulfur standards will have a net benefit to public health due to reduced emissions of harmful compounds. The composition of the emissions from combustion of low sulfur gasolines will be different than the composition of the emissions from the high sulfur gasolines they replace. Furthermore, other changes to the composition of the gasoline are likely to accompany the reduction in sulfur content. While some of these changes may involve increases in the content of certain compounds that tend to lead to more harmful emission products, we believe that the improved catalyst performance enabled by the low sulfur fuel will more than offset any slight increase in harmful emissions that would otherwise result (if sulfur levels remained constant but the other properties were increased).

It is difficult to quantify this impact because it depends on the specific approaches that each refiner takes to reduce their gasolines' sulfur levels, as well as the composition of the gasoline overall. However, some general trends can be identified, and based on these trends we have drawn the conclusion that low sulfur gasoline will pose no new, increased risk to human health relative to the higher sulfur gasoline it replaces.

Some refiners already make gasolines that meet the proposed standards. Others will make modest changes in the way in which they blend refinery streams to produce low sulfur gasoline. But most refiners will have to install some desulfurization technology and/or otherwise substantially change their operation. If a refiner chooses a traditional route to desulfurize gasoline, he will likely select a desulfurization technology which has the undesirable side effect of reducing the octane content of the gasoline streams. To make up that octane, the refiner has several options. All of these options, whether increasing the aromatics or olefins content of the gasoline through other processing changes, or through the addition of oxygenates such as ethanol or MTBE, could lead to increased emissions of air toxics (benzene, 1,3-butadiene, aldehydes) if the emissions performance of the vehicle catalyst remained constant. However, since low sulfur gasoline will enable very low emitting catalysts and will improve the performance of existing catalysts, the catalyst will be able to convert these toxic emissions into less harmful compounds. Because of the diversity among refineries, it is impossible to estimate with any certainty how many refiners may choose this route.

If a refiner chooses one of the improved technologies for sulfur removal, the technologies on which much of our economic analysis for this proposal is based (as discussed in Sections IV.C and IV.D of the Preamble), there will be less of a need to increase high octane compounds in the gasoline. These improved technologies are designed to reduce the octane loss that occurs with the traditional technologies. Because the need to increase high octane components is reduced if these technologies are used, the net benefit of low sulfur gasoline is even greater, because there are even fewer toxic compounds for the catalyst to have to convert. (No catalyst yet developed is able to convert 100 percent of the pollutants that come from the engine.)

Appendix D. References:

1. *EPA Staff Paper on Gasoline Sulfur Issues* (EPA420-R-98-004), May 1998.